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FILAMENT-WINDING FABRICATION OF QCSEE CONFIGURATION FAN BLADES

by Sam Yao

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Gardena, California 90248

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16. Abstract

The objective of this program was to design and fabricate twelve NASA-QCSEE type composite fan blades utilizing wet filament winding fabrication techniques. All composite fibers were continuous and attached to the root end. All components were formed, bonded and co-cured in one molding process. Advanced fiber materials used in the blade fabrication were Thornel-300, Carbolon Z-2-1 and Carbolon Z-3 graphite in an epoxy resin matrix.

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FOREWORD

This report presents the work accomplished by Fiber Science, Inc. during the period May 1976 to August 1977 on NASA Contract NAS3-20099, "Filament-Wound Spar Shell Fan Blades". The work was administered by the National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio with Mr. Morgan Hanson, Project Manager.

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SUMMARY

A filament-wound spar shell fan blade in which all the fibers are continuous and attach to the root end was designed and fabricated. The blade external configuration conformed to the NASA-QCSEE fan blade except for the root end. The blades were constructed with different types and mixtures of fibers in an epoxy resin matrix. The fiber types were Thornel 300 graphite, Carbolon Z-2-1 and Z-3, and S-2 glass. A steel root end trunnion was incorporated in each blade and a .012 inch thick type 301 stainless steel leading edge protective shield was incorporated on eight of the blades.

A total of 12 blades were fabricated and delivered to NASA for testing.

INTRODUCTION

Large fan blades contribute significantly to the weight of current turbofan engines. Replacement of metal fan blades with a composite blade design has the potential of reducing fan blade weight. To be competitive with metal blades, composite blades must be cost effective and be resistant to foreign object damage (FOD). Fabrication of composite fan blades that utilize the filament-winding technique provides the potential for being cost effective. Improved resistance to FOD could be expected because of the continuous filament structure.

The objective of this program was to design and fabricate twelve NASA-QCSEE (Quiet Clean Short-Haul Experimental Engine) type fan blades utilizing filament-winding fabrication techniques. Advanced fiber materials used in the blade fabrication were Thornel-300, Carbolon Z-2-1 and Carbolon Z-3 graphite in an epoxy resin matrix.

NDE, fatigue and impact studies of the blades will be performed under a separate program.

BLADE DESIGN

The QCSEE fan blade was used for baseline shape and structural performance. The final design configuration of the blade is shown in Figure 1. The blade consisted of a spar, shell, wedge, trunnion, and leading edge shield.

The spar was of unidirectional fibers which were continuous and wrapped around the wedge pinned to the root end trunnion. The amount of fibers was sized to completely fill the shell cavity at the tip end of the blade. The fibers were used to provide span-wise strength.

The wedge provided a wrap around point for the unidirectional fibers of the spar. A series of fiberglass fins were incorporated to the wedge and are shown in Figure 2. The primary purpose of the fins was to provide additional shear ties between the unidirectional fibers and to prevent interlaminar tension failure at that region. The ιins also guided the fibers in their proper paths and prevent the fibers from crossing over each other.

The shell was $\pm$ 45° helically wound and tied to the root end trunnion at the grooved area. The helically wound shell was mainly to provide strength in both torsional and chordwise directions.

The root end trunnion was integrated into the blade in order to eliminate the dovetail connection as used in

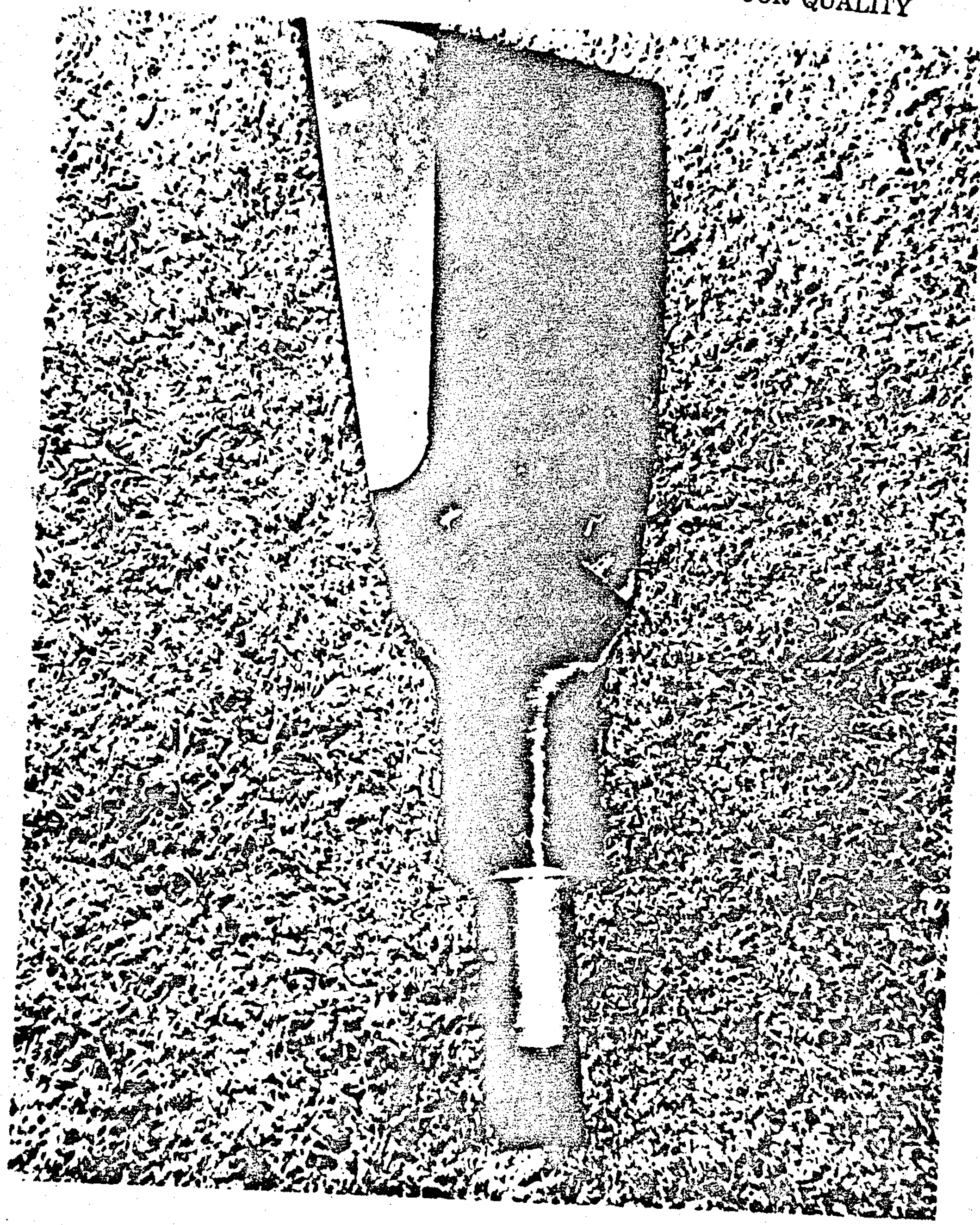

FIGURE 1. FILAMENT-WOUND SPAR SHELL FAN BLADE

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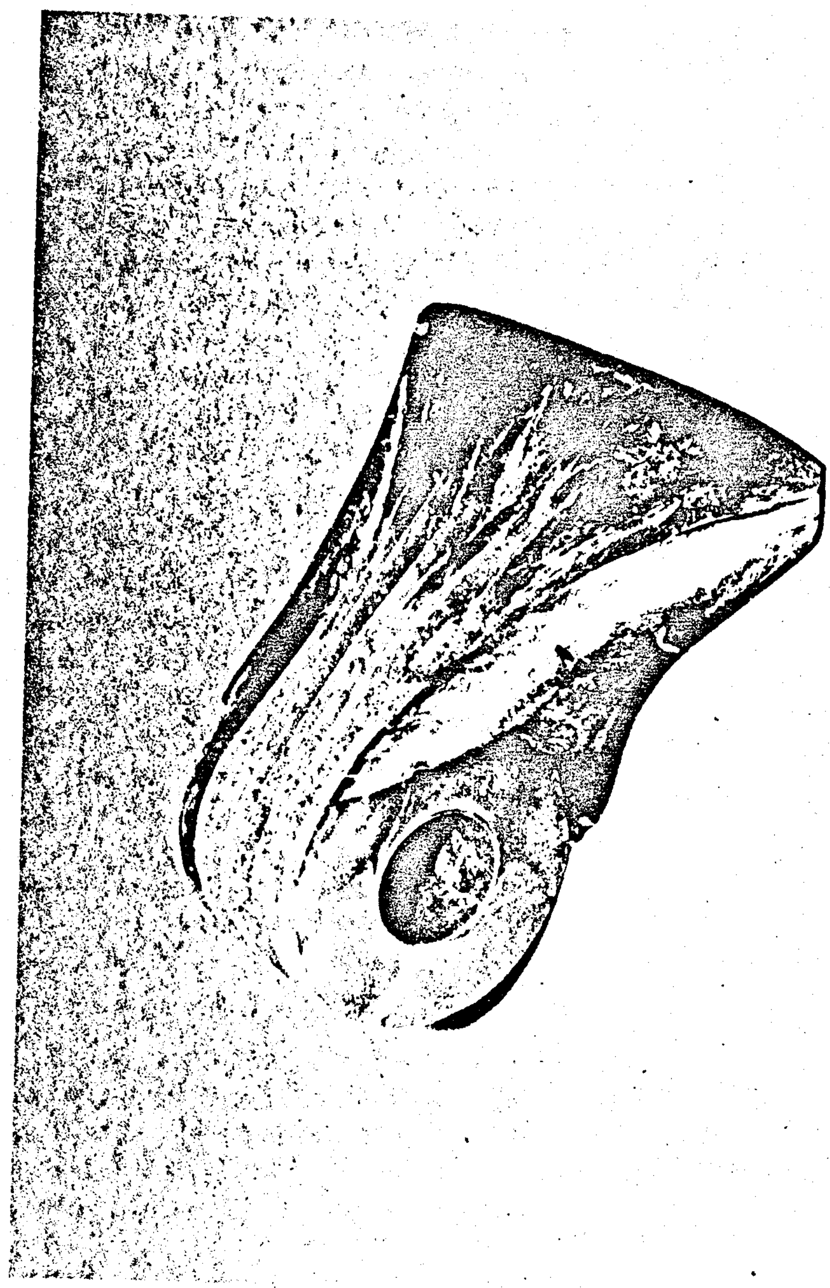

FIGURE 2. ROOT END WEDGE

the NASA-QCSEE blade. Both the spar and shell were directly tied to the trunnion. The configuration of the trunnion is shown in Figure 3. Since the trunnion was not a part of this investigation, no attempt was made to design a light weight configuration. The material of the trunnion was E4130 steel heat treated to 150,000 psi.

The metallic shield was incorporated in the leading edge of the blade for erosion protection. The shield was of .012 inch thick stainless steel, type 301, 1/4 hard condition.

FIGURE 3. ROOT END TRUNNION

TOOLING

The tooling required for this program other than a filament winding machine was the blade forming mold, shell winding fixture, spar winding fixture, and wedge mold.

The blade forming mold is shown in Figure 4. It was a split type female mold. The mold was constructed with high temperature glass/epoxy laminate having highly polished plastic gel coat contoured mold surfaces.

The shell winding fixture consisted mainly of two shaped aluminum bars which connected two root-end trunnion -- one at each end -- and provided proper spacing for winding the shell of the blade to size. Figure 5 shows the fixture connecting the trunnions together.

The spar winding fixture is shown in Figure 6. The fixture was of metallic construction and used to wind unidirectional fibers to desired paths.

The wedge mold is shown in Figure 7. The construction of the mold was high temperature fiberglass laminate. It was a split type female mold. The mold was used for casting the wedge.

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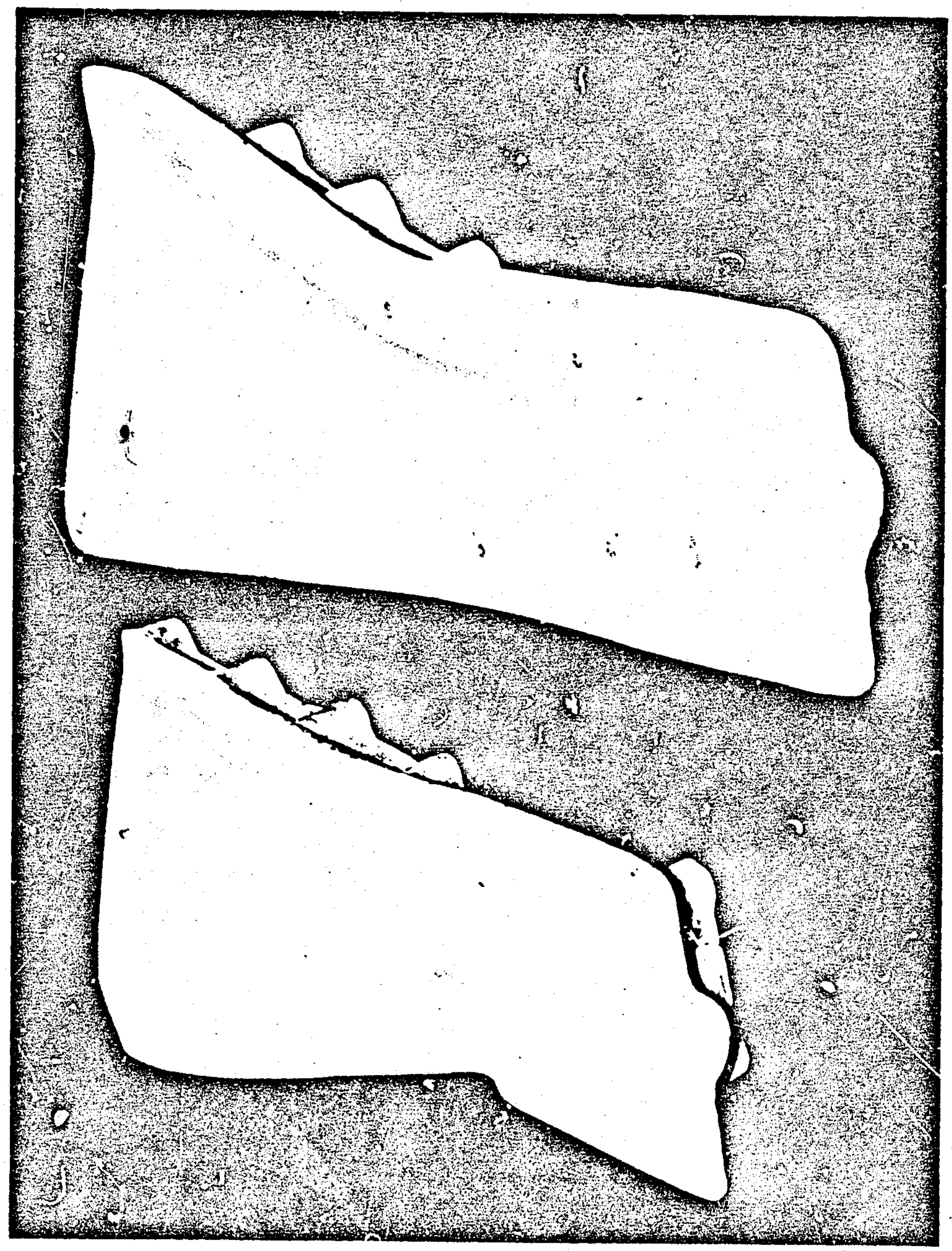

FIGURE 4. BLADE FORMING MOLD

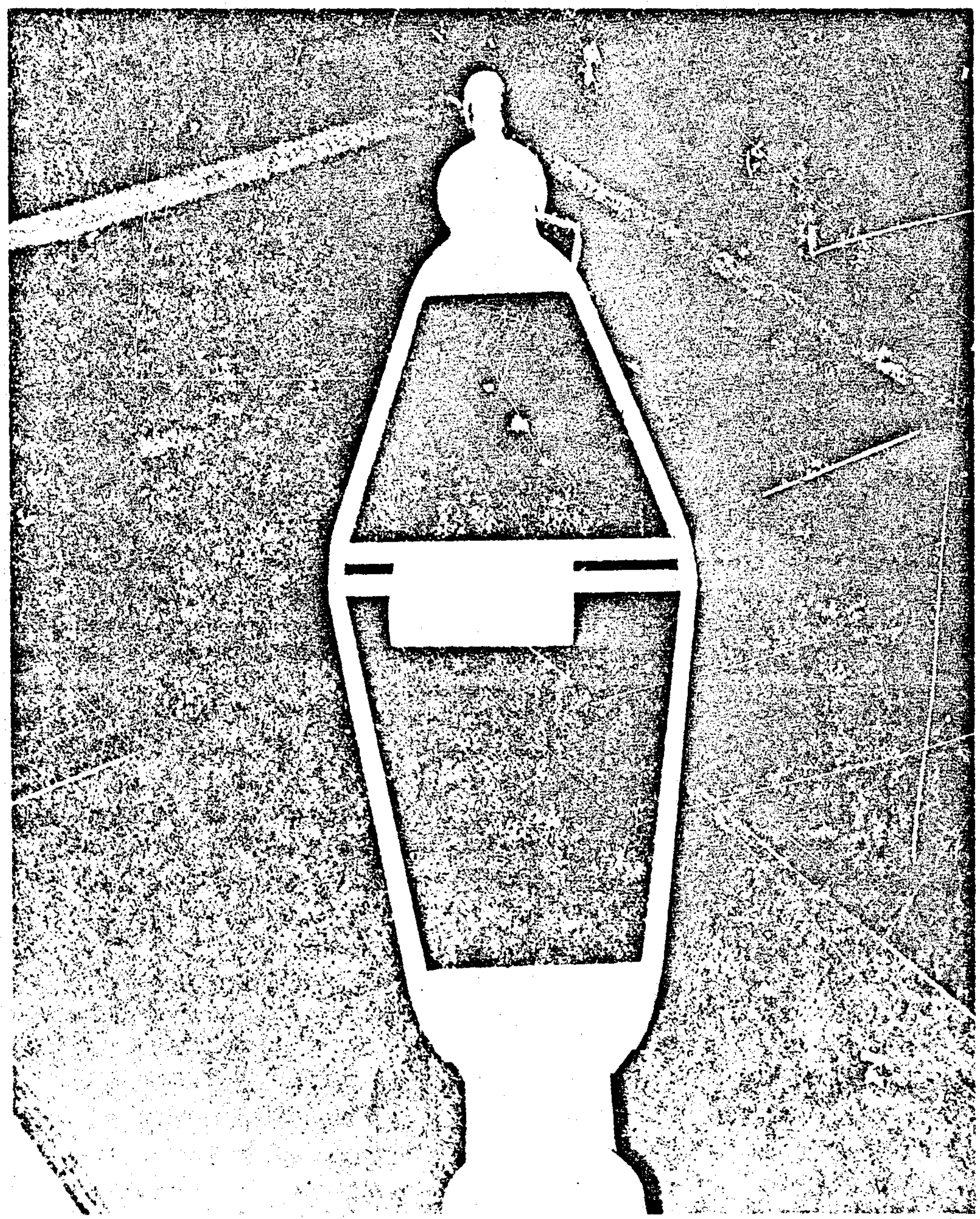

FIGURE 5. SHELL WINDING FIXTURE

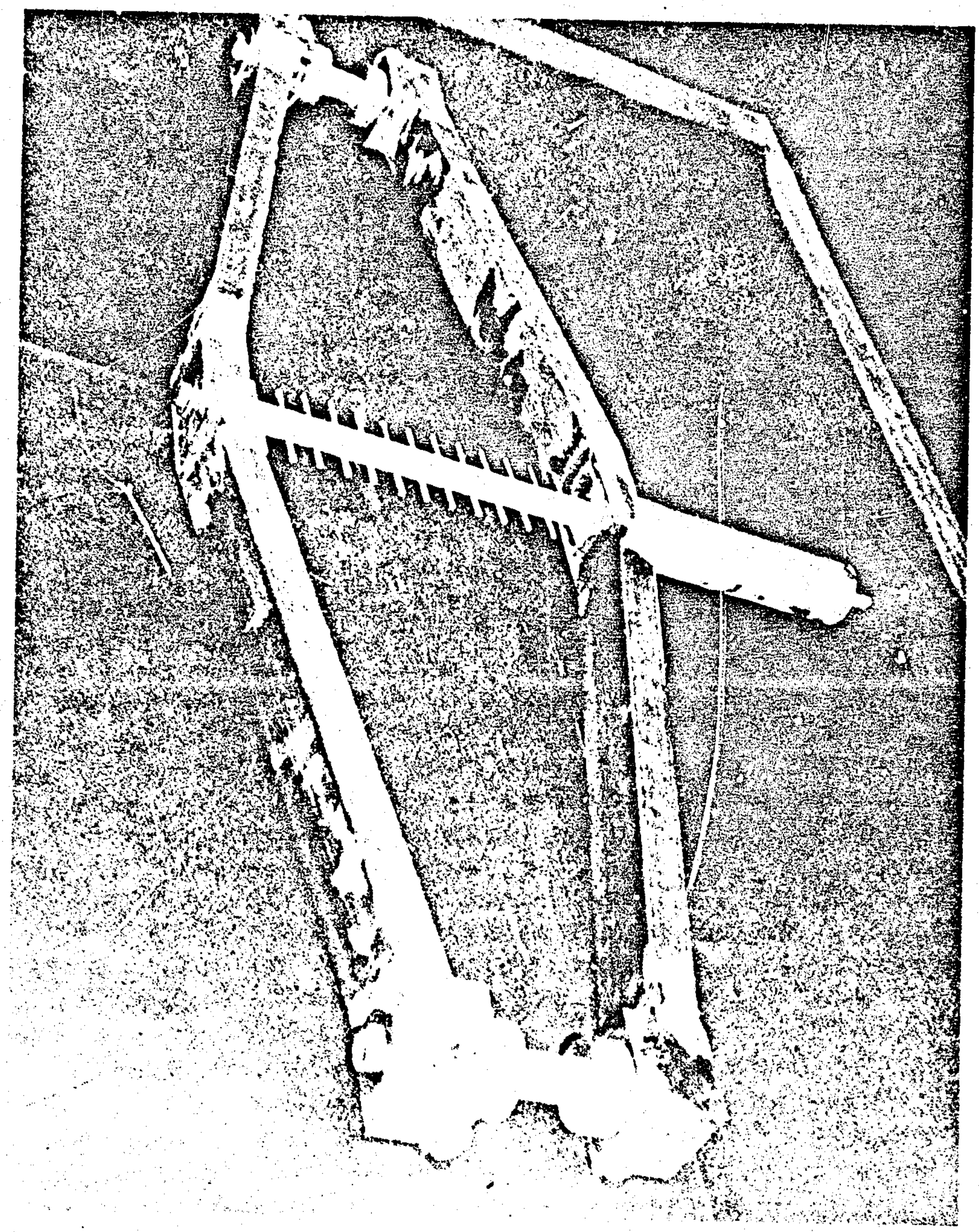

FIGURE 6. SPAR WINDING FIXTURE

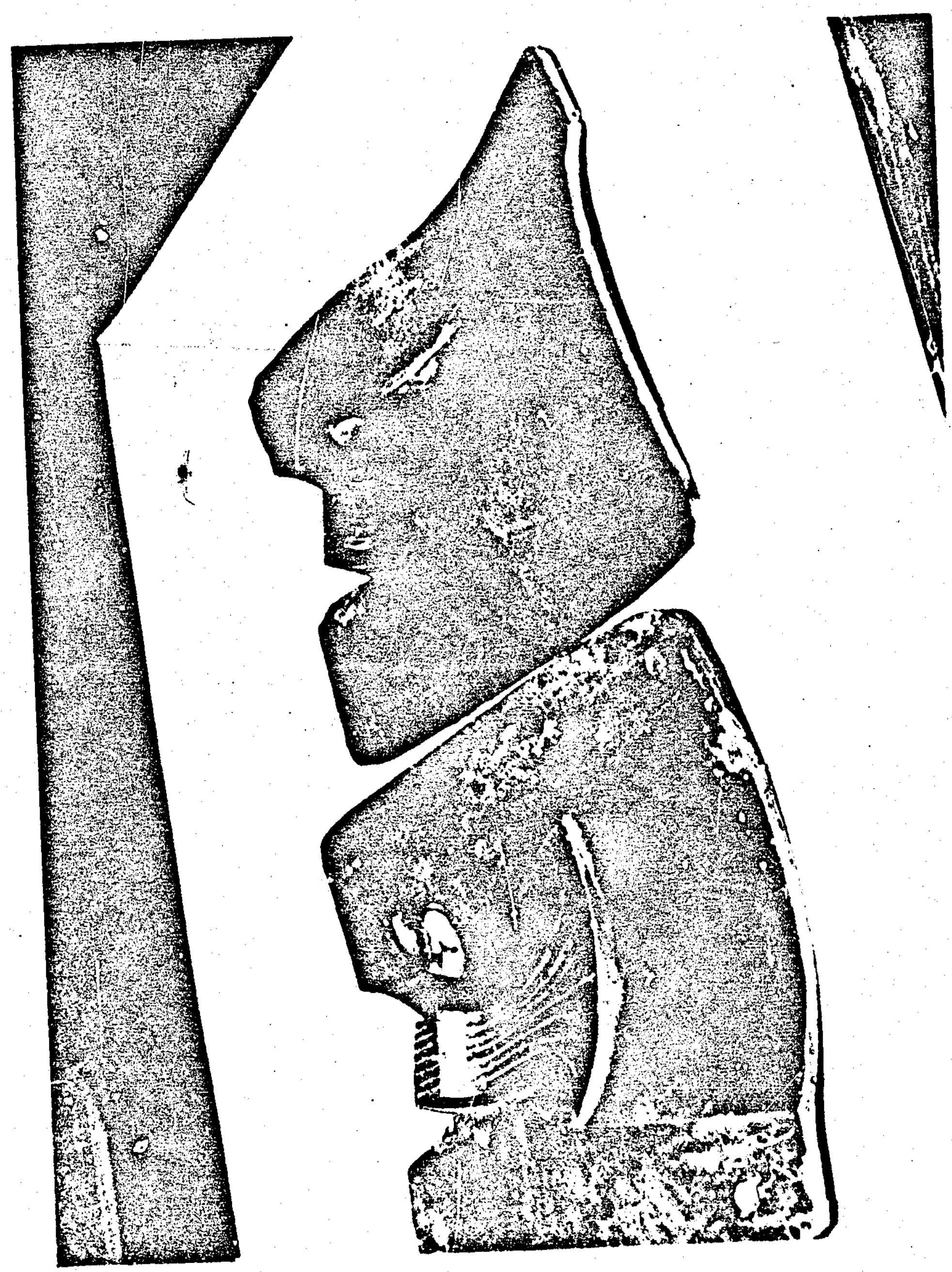

FIGURE 7. ROOT END WEDGE MOLD

FABRICATION

The blade shell and spar were all fabricated by the direct impregnation filament winding technique and post forming (GeoForm) process developed by Fiber Science, Inc.

Twelve blades were fabricated in this program. The materials used in the blade fabrication are summarized in Table I, attached.

All fiber materials were impregnated with APCO 2434/APCO 2347 epoxy resin system manufactured by Applied Plastics Company, El Segundo, California.

The wedge and trunnions were prefabricated prior to filament winding. The wedge was casted with chopped graphite/epoxy. Fiberglass (glass fabric/epoxy) fins were installed during the casting process.

The unidirectional fibers were wound around the wedges to form the spar of two blades. Subsequently, the wound assembly was placed on the shell winding fixture. The shell winding encapsulated the spar and tied the root-end trunnion in place. All of the winding processes were done for a set of two blades with a tip-to-tip arrangement.

After winding the shell for two blades, the assembly was parted at its mid-span into two. Each blade was positioned in the blade forming mold cavity. The leading

TABLE I, BLADE FABRICATION MATERIALS

Fabrication Materials	Blade Number											
	1	2	3	4	5	6	7	8	9	10	11	12
Spar												
T-300 graphite fiber 100%	X	X			X	X						
T-300 graphite fiber 90%											X	X
T-300 graphite fiber 80%							X	X				
Z-2-1 Carbolon fiber			X	X								
Z-3 Carbolon fiber									X	X		
S-2 glass fiber 10%											X	X
S-2 glass fiber 20%							X	X				
Shell												
T-300 graphite fiber 100%	X	X			X	X						
T-300 graphite fiber 80%							X	X			X	X
Z-2-1 Carbolon fiber			X	X					X	X		
S-2 glass fiber 20%							X	X			X	X
Wedge												
With fins		X		X	X	X	X	X			X	X
Without fins	X		X									
L.E. Shield					X	X	X	X	X	X	X	X

edge metallic shield with a piece of film adhesive in place was installed before closing the mold. The blade assembly was pressurized internally with syntactic foam as a pressure medium through a passage at the trunnion. The blade was cured at a final temperature of 250^{o}F. The cured blade was then trimmed to length and finished.

The weights of the blades are summarized in Table II, attached.

TABLE II, BLADE WEIGHTS

Blade S/N	Metallic Components			Composite lb	Total lb
	Trunnion lb	Pin lb	L.E. Shield lb		
1	12.4	1.1	---	5.25	18.75
2	12.4	1.1	---	5.25	18.75
3	12.4	1.1	---	5.20	18.70
4	12.4	1.1	---	5.20	18.70
5	10.5	1.1	.20	5.90	17.70
6	10.5	1.1	.20	5.90	17.70
7	10.5	1.1	.20	5.95	17.75
8	10.5	1.1	.20	5.95	17.75
9	10.5	1.1	.20	5.96	17.60
10	10.5	1.1	.20	5.96	17.60
11	10.5	1.1	.20	5.90	17.70
12	10.5	1.1	.20	5.90	17.70

RESULTS

Twelve fan blades were successfully fabricated by utilizing the GeoForm process. The blades were of a single type fiber as well as a mixture of fibers. A metallic leading edge shield was successfully bonded and co-cured with the blade. All the design and fabrication objectives of this program were successfully met.

CONCLUSIONS & RECOMMENDATIONS

It is concluded that the spar shell composite QCSEE blade can be successfully fabricated by employing the wet filament winding technique and subsequently forming into the required contour. All components can be assembled, formed, bonded and cured together in one integral unit. This program demonstrated an efficient design with a simple manufacturing process for a QCSEE fan blade.

It is recommended that different spar shell designs be studied where the relation between the spar unidirectional and skin hoop and/or helical fiber relations be varied in order to optimize the impact resistance of the blade. Also, it is proposed to eliminate the metallic root end trunnion by extending the composite structure and attaching directly to the windings.